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THE EFFECT OF NARROWING SOURCE BEAM ON CONVERGENCE ZONE WIDTH, (U)
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10 by
D. F. Gordon

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THE EFFECT OF NARROWING SOURCE BEAM ON CONVERGENCE ZONE WIDTH

This note presents some ray computations to demonstrate how restricting the vertical angle at which rays are emitted at the source diminishes the width of the convergence zone. This is not a complete study and the note is not to be considered as a formal report.

These computations were done to aid in evaluating a proposed sonar system. Since they shed some light on the relation between vertical beam width and zone width, the results are summarized here. The sound velocity profile is from the area ^{8 deg.} 30° N ^{8 deg.} 120° W as measured in February. Figure 1 shows the profile as fitted by the standard curvilinear segment profile-fitting computer program of Code 503¹. Subsequent ray computations were done by the standard ray intensity program of Code 503¹. All ray arrivals at a given range are added in random phase and expressed as propagation loss in dB.

A single source depth of 202.3 yards is used. Let θ be the angle at the source between the ray and the horizontal. Positive ray angles are directed upward at the source and negative ray angles downward. Bottom reflected rays are omitted from this computation which, in this case are rays for which $|\theta| > 13.1^{\circ}$. Rays for which $|\theta| = 9.8^{\circ}$ become horizontal at the maximum velocity in the surface duct. Rays with greater values of $|\theta|$ penetrate into the surface duct and reflect from the surface. Rays for which $|\theta| < 9.8^{\circ}$ are refracted in the thermocline and do not touch the surface.

1. Navy Electronics Laboratory Report 1105. A New Ray Intensity Procedure For Underwater Sound Based On a Profile Consisting of Curvilinear Segments by M. A. Pedersen, D. F. Gordon, and A. J. Keith, 30 March 1962 (Conf.)

These rays of angle less than 9.8° will have a direct refracted path to the zone. Therefore their use may have some operational advantage such as less reverberation, less background noise, or less distortion. However, the width of the zone is reduced if the vertical beam width is reduced to include only these rays. If the vertical beam width is further reduced, the zone will diminish in width and finally disappear, first near the surface and then at depths approaching the source depth.

This reduction in zone width is shown in Figures 2 and 3. The left hand side of Figure 2 shows the full zone for a receiver depth of 91.4 yds. This is 15 yards below the surface duct. Because no bottom reflected rays are included in the computation, the area preceeding the zone is not insonified. At the trailing edge of the zone, a complete shadow does not exist because a small amount of energy is guided to long ranges by the vertical sound velocity gradient at the bottom of the surface duct. The angle of the ray which forms the caustic is indicated at each caustic. For instance, the caustic at shortest range is formed by the ray which leaves the source at an angle of 8.6° below the horizontal, forms a nadir in the deep ocean and arrives at the receiver depth traveling upward.

At the right side of Figure 2, the zone is depicted for rays which are less than 9° from the horizontal at the source. Here only two caustics remain. Rays must have an angle of 8.6° or greater to reach the depth of 91.4 yards, so only a narrow cone of rays can reach this depth and only two short range intervals are insonified. The ray angles to the caustic are 0.01° greater than this minimum of 8.6° .

Figure 3 shows the zone for a receiver depth of 182.9 yds. Two caustics lie at nearly the same range of 50.4 kyds, formed by rays of -3.4 and -6.3° .

The zone is shown for 3 groups of rays or 3 vertical beams: all rays (except bottom reflected), rays within 9° of the horizontal, and rays within 6° of the horizontal. For $|\theta| < 9^\circ$, the three surface reflected caustics beyond 55 kyds are omitted. At $|\theta| < 6^\circ$, only two caustics remain although rays exist quite close to the caustics at $\pm 6.3^\circ$. Away from the caustics, loss levels are generally 1 or 2 dB greater for this case of $|\theta| < 6^\circ$ because some arrivals are absent.

CONCLUSIONS

For the given case, if rays are restricted to angles more horizontal than those that reach the surface, the zone width is greatly reduced. The zone width is decreased to near zero for receiver depths near the surface and decreased by about 50% for receiver depths near the source depth. The loss levels in the portion of the zone that remains are not seriously degraded, even when the zone width is seriously degraded. This suggests that vertical scanning with a narrow beam might have useful application.

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Figure 1. Sound velocity vs depth profile.

Figure 2. Convergence zone for full vertical beam and restricted beam for source at 202.3 yds. and receiver at 91.4 yds.

Figure 3. Convergence zone for full vertical beam and restricted beams for source at 202.3 yds and receiver at 182.9 yds.





